(12) UK Patent Application (19) GB (11) 2 299 915 (13) A

(43) Date of A Publication 16.10.1996

(21) Application No 9606243.5

(22) Date of Filing 25.03.1996

(30) Priority Data
(31) 9504386 (32) 12.04.1995 (33) FR

(71) Applicant(s)
Schlumberger Limited

(Incorporated in the Netherlands Antilles)

277 Park Avenue, New York, NY 10172, United States of America

(72) Inventor(s)
Kamal Babour

(74) Agent and/or Address for Service
B D Stoole
Schlumberger plc, 1st Floor 1 Kingsway, LONDON, WC2B 6XH, United Kingdom

(51) INT CL^6
E21B 47/12 , G08C 17/04 , H04B 13/00

(52) UK CL (Edition O)
H4L LX4
E1F FHK
U1S S1748

(56) Documents Cited
GB 2292869 A US 5189415 A US 4992787 A
US 4800385 A US 4302757 A US 4160970 A
US 4057781 A US 3967201 A

(58) Field of Search
UK CL (Edition O) H4L LCAX LCC LCX
INT CL^6 E21B 47/12 , G08C 17/04 , H04B 13/00 13/02
ON-LINE : WPI

(54) Communication along a drill string

(57) Information regarding drilling parameters in a drilling operation is communicated from the drill head by a downhole radiating antenna 16 in the well 10. The antenna 16 propogates electromagnetic waves 18 through the surrounding formations, the drill string 20 and the drilling rig 12. Measurements are made of the magnetic field produced at the surface caused by the current flowing along the drill string 20 and the rig 12. These measurements may be made by a directional magnetometer 24 which measures the magnetic field in a direction orthogonal to the axis of the drill string. Use is envisaged in both onshore and offshore wells.

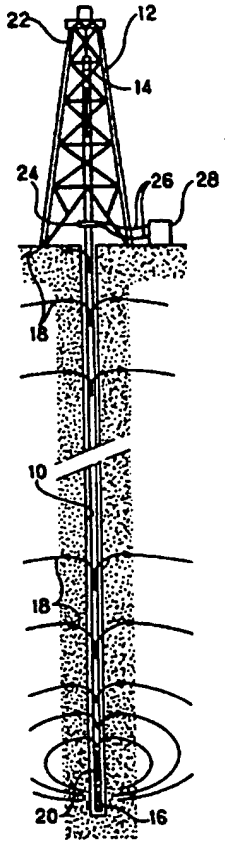

Fig.1

GB 2 299 915 A

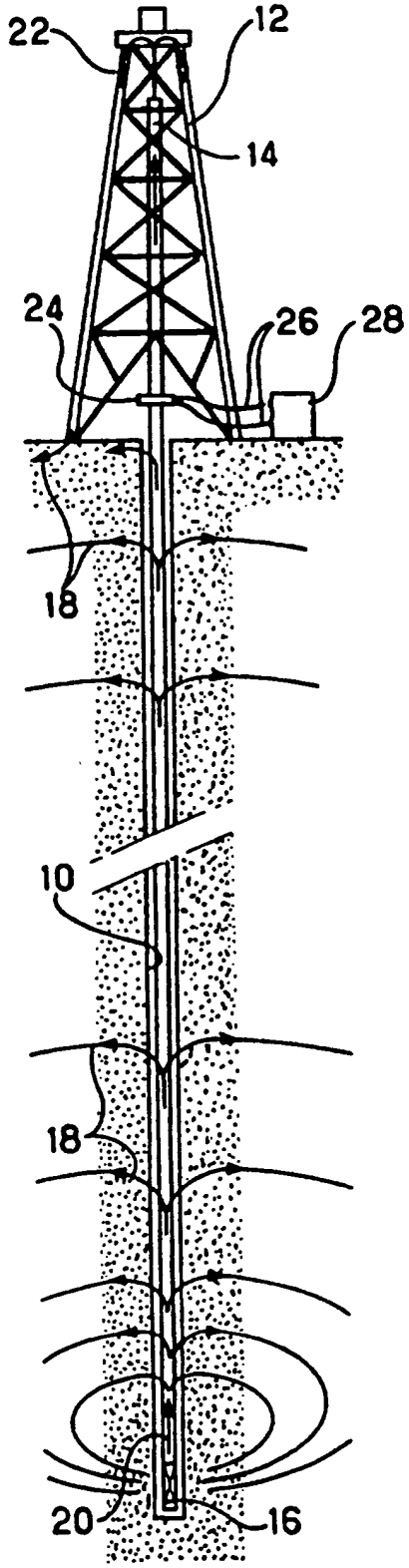

Fig.1

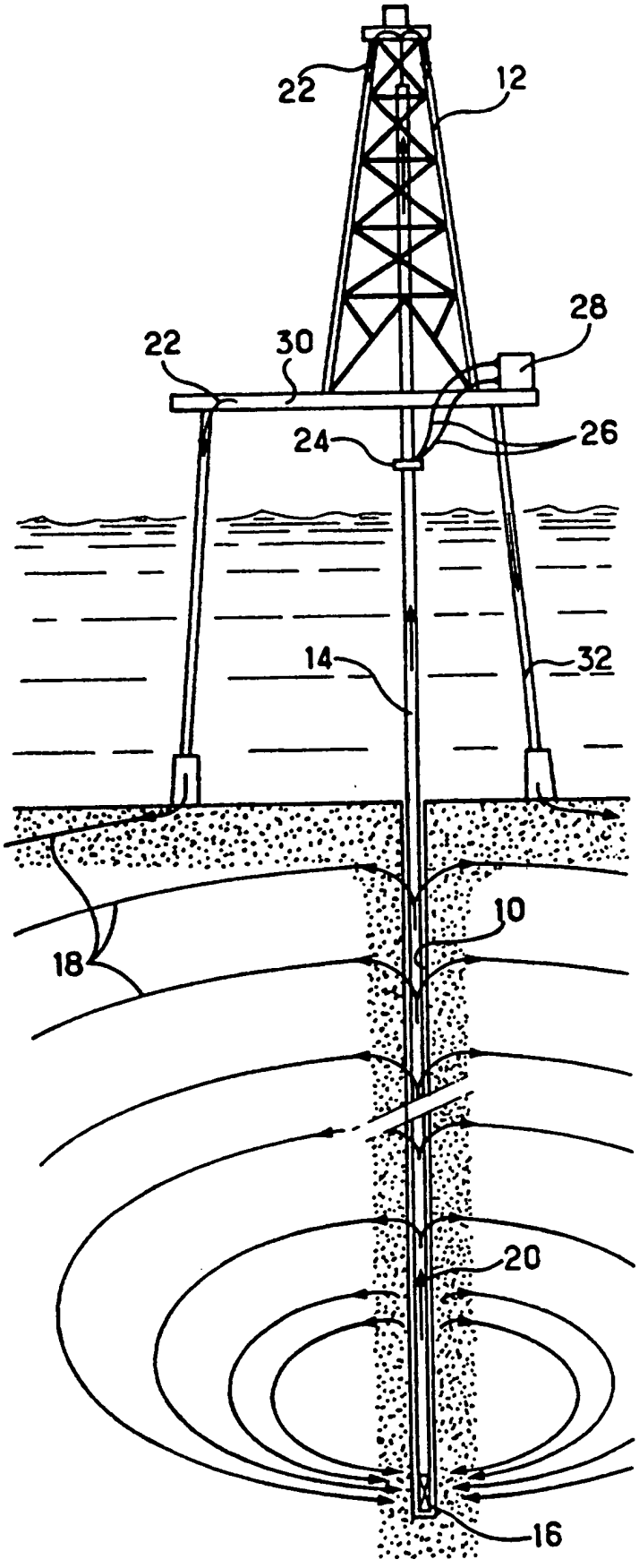

Fig.2

2299915

A METHOD AND APPARATUS FOR SURFACE DETECTION OF ELECTROMAGNETIC SIGNALS RADIATED FROM DOWN A WELL

DESCRIPTION

Technical field

The invention concerns a method which allows real-time detection at the surface of electromagnetic signals radiated from down a well by a radiating antenna mounted on a string of rods suspended from a rig.

The invention also concerns apparatus implementing this method.

The invention is applicable in all cases in which it is desired to make information, such as results from measurements made down a well, available in real time at the surface. A special application concerns the field of oil wells and the invention can be used equally well with offshore wells and onshore wells.

State of the art

At various stages in the life of an oilwell, for example during exploration and at the beginning of production, physical measurements are made "downhole", such as measurements of temperature, pressure, flow, etc.

In order to provide this information at the surface, a conventional solution consists in associating recording apparatus with the measuring instruments, the information being stored in the apparatus. The user then only has access to the information when the recording apparatus is raised to the surface again, i.e. when all the measurements have been effected.

In many cases, however, it is desirable to make information available at the surface in real time, e.g. in order to take account of the results of initial measurements in the subsequent operations effected downhole.

These problems can be overcome by using a technique of transmitting signals in real time over an electromagnetic channel, as disclosed in the documents US Patents 3,831,138, 4,015,234 and 4,160,970. According to that technique, a radiating antenna is disposed downhole, the antenna being an electrical dipole to which an electrical voltage is applied as modulated by the information to be transmitted. The modulated electromagnetic waves radiated by the dipole are transmitted to the surface through the geological formations. In order to detect the modulated electromagnetic waves radiated downhole, it is usual to use two electrodes buried in the ground at a certain distance apart from one another, so as to measure a

potential difference along one of the current lines induced in the soil by the modulated electromagnetic waves radiated by the dipole. Cables connect the electrodes to a receiver in which the signals thus measured are demodulated, amplified, and processed.

That solution is relatively awkward to implement, and is used solely in the case of onshore bore holes. If it is desired to avoid risk of damage to the cables which connect the electrodes to the receivers, they must be protected, which may be effected in particular by burying them shallowly. Setting up the apparatus can therefore be relatively protracted and costly.

Moreover, industrial exploitation of that technique in the case of offshore wells is unrealistic. Thus, installing electrodes on the sea bed and installing cables of great length to connect these electrodes to receivers would require a particularly cumbersome and costly material outlay. Moreover the conditions in which the electrodes and cables would have to be installed are often very difficult and would be hard to accept, because of the risk of accident involved. Furthermore, even if installation could be effected, the risk of accidental breaks in the cable during measurements would be very high.

As is illustrated in US Patent 4,691,203, it has also been proposed to detect at the surface electromagnetic signals radiated downhole, by means of a transformer connected in a cable of which one end is connected to the top end of the string of rods and of which the opposite end is buried in the ground. The secondary of the transformer is connected to a receiver, which analyses the current circulating in the string of rods and thence in the cable while the electromagnetic signals are being radiated.

In practice, the reception technique described in that document suffers as badly as the preceding technique in relation to the cost and time taken for installation, particularly because of the need to bury a cable over a certain length. That operation is particularly difficult in the case of hard or stony ground.

Moreover, the sensitivity of the system appears to be relatively limited, firstly because the use of a transformer to detect the current circulating in the cable introduces electrical resistance into the circuit, and also because the contact impedance of the cable in the ground is very high relative to the contact impedance of the system supporting the rods.

Finally, applying that reception technique to an offshore bore hole is again hard to envisage within the framework of commercial use.

Summary of the invention

The invention specifically provides a novel method which allows detection at the surface of electromagnetic signals radiated downhole, in such a manner that the method can be implemented equally well offshore and onshore, and in a manner that is particularly rapid and cheap.

The invention also provides apparatus for implementing this method.

According to the invention, this result is achieved by means of a method of detecting electromagnetic signals in real time and at the surface, which signals are radiated down a well from a string of rods suspended from a rig, comprising the steps of measuring the magnetic induction produced at the surface by the string of rods in response to a current flowing along the string of rods and along the rig during the radiation of the electromagnetic signals.

In a preferred implementation of the invention, the magnetic induction is measured by means of a directional magnetometer fixed on the string of rods in such a manner as to make a measurement in a direction substantially orthogonal to the axis of the string of rods.

When the method is applied to an offshore well, the magnetic induction is measured immediately above sea level.

In like manner, when the method is applied to a well on land, the magnetic induction is measured immediately above the ground.

In all cases, the setting up of the apparatus adapted to receive the signals at the surface is effected in a particularly short time (some minutes), at limited cost and without risk of the apparatus being damaged as can happen to cables running on the ground or under the sea.

Furthermore, the principle of measurement makes it possible to recover signals which are easy to exploit, particularly because no parasitic resistance is introduced into the circuit and because the contact impedance of the rig is considerably less than that of a cable.

The invention also provides apparatus for detecting electromagnetic signals in real time and at the surface, which signals are radiated down a well from a string of rods suspended from a rig, the apparatus comprising means for measuring the magnetic induction produced at the surface by the string of rods in response to a current flowing along the string of rods and along the rig during the radiation of the electromagnetic signals.

Brief description of the drawings

Two preferred embodiments of the invention are now be described, by way of non-limiting example, with reference to the accompanying drawings,

in which:

- Figure 1 is a schematic view, partially in section, of an onshore oilwell, with a string of rods suspended from a rig and apparatus for detection at the surface in conformity with the invention; and

- Figure 2 is a schematic view in section like Figure 1, illustrating an offshore oilwell including apparatus for detection at the surface in conformity with the invention.

Detailed description of the preferred embodiments

In Figure 1 the reference 10 denotes a well, such as an oilwell on land, which has already been drilled. This well is surmounted by a rig 12 anchored to the surface of the ground.

In order to effect some physical measurements down the well 10, a string of rods 14 has been lowered down the well, suspended from the rig. The string of rods 14 has some measuring instruments (not shown) in known manner in its bottom end, a power supply (not shown) powering the measuring means, electronic circuits (not shown) for transforming the signals from the measuring instruments into modulated electrical signals and a radiating antenna 16, which transforms the signals into modulated electromagnetic signals. The radiating antenna is normally constituted by a dipole. These apparatuses and circuits are implemented in known manner, as shown for example in the documents US Patents 3,831,138, 4,015,234 and 4,160,970. They are not part of the invention and they are therefore not described here in more detail.

The electromagnetic signals radiated by the radiating antenna 16 create current lines 18 in the ground around the well 10, all of which loop back to the string of rods 14 and are axisymmetrical about the vertical axis of the well. More specifically, an upwardly flowing electrical current, modulated as a function of the electromagnetic signals radiated by the radiating antenna 16, flows up the string of rods 14, as indicated by the arrow 20 in Figure 1, and then flows back down to the radiating antenna 16, following the current lines 18.

Part of the current which flows up the string of rods 14 continues above the surface of the ground and flows in the rig 12, before returning to the bottom of the string of rods 14 via other current lines 18. The path of the current in the rig 12 is indicated by the arrows 22 in Figure 1.

In conformity with the invention, the magnetic induction B produced immediately above the ground by the string of rods 14, in response to the

current which flows along the string of rods, and then through the rig 12, is measured while the electromagnetic signals are being radiated by the radiating antenna 16. More specifically, the means for measuring magnetic induction comprise a directional magnetometer 24 fixed on the string of rods 14, above the surface of the ground. The orientation of the directional magnetometer is such that it measures the magnetic induction in a direction substantially orthogonal to the axis of the string of rods.

In accordance with Ampère's law, if the distance between the magnetometer and the axis of the string of rods 14 is denoted R (in meters), and the current which flows at this level along the string of rods is denoted I (in amps), then the value of the magnetic induction B (in nT) is given by the formula $B = 200\ I/R$.

The directional magnetometer 24 can be any magnetometer having good sensitivity, whose size is compatible with the surroundings at the foot of the rig and which is adapted to pass the frequencies of the electromagnetic signals radiated downhole, generally lying in the range 0.5 Hz to 150 Hz. In particular it may be an induction coil aligned in a direction orthogonal to the string of rods.

The magnetometer 24 is attached to the outside of the string of rods 14 by any suitable means allowing rapid and effectual attachment and removal. In particular a collar (not shown) may be used, formed by two semicircular parts, one of which carries the magnetometer. These two parts are clamped on to the string of rods and connected together by nuts and bolts or any equivalent releasable fixing means.

As illustrated very schematically in Figure 1, the directional magnetometer 24 is connected by electrical conductors 26 to a receiver circuit 28, which can be installed on a truck or placed directly on the ground right beside the magnetometer.

The receiver circuit 28 receives a voltage modulated as a function of the variation in the magnetic induction detected by the magnetometer, that is to say as a function of the variations in the current which flows above the ground along the string of rods 14 and then into the rig 12, under the influence of the modulated electromagnetic signals produced downhole by the radiating antenna 16. This receiver circuit 28 is designed like a receiver circuit used in existing detection techniques, i.e. in the detection of modulated electromagnetic signals effected at the surface with the aid of two electrodes embedded in the ground. Thus, the signals provided by the magnetometer 24 are comparable with the signals which appear at the terminals of the electrodes used in a conventional reception

technique. The receiver circuit 28 thus provides amplification, filtering and processing of the signals from the magnetometer, so that these signals can be employed in real time by the user. To this end, the receiver circuit 28 is advantageously provided with a display screen (not shown), in a manner also comparable with the conventional technique.

The receiver circuit 28 per se does not form part of the invention. Accordingly, it is not described in the present application.

The description given with reference to Figure 1 shows that the detection apparatus at the surface in conformity with the invention is particularly simple and of low cost. Moreover, it can be installed in a particularly short time, whatever the nature of the terrain in which the well is located and without risk of the equipment being damaged by moving vehicles or machinery in the vicinity of the rig.

A second embodiment of the invention is shown in Figure 2, and it differs from the preceding embodiment essentially in that the detection apparatus at the surface is associated in this case with an offshore well, instead of being applied to an onshore well.

More specifically, a well 10 already drilled in the sea bed is shown in Figure 2. This well is surmounted by a platform 30, which rests on the sea bed via legs 32. The platform 30 carries in particular a rig 12, from which there is suspended a string of rods 14 with its bottom end received in the well 10, in the same manner as in the onshore well of Figure 1.

The string of rods 14 is fitted with the same equipment at its bottom end as has been described briefly with reference to Figure 1. In particular, this equipment includes a radiating antenna 16 which can provide modulated electromagnetic signals, in a manner well known to the person skilled in the art.

These modulated electromagnetic signals induce current lines 18 in the ground. As in the case of an onshore well, the radiation of modulated electromagnetic signals by the radiating antenna 16 causes a current 20 to flow up the string of rods 14, with a portion being returned to the bottom of the string of rods 14 by the current lines 18.

Another portion of the current 20 flows up along the string of rods 14, above the sea bed, up to the drilling platform 30 and the rig 12. This portion of the current 20 loops back to the radiating antenna 16 by then flowing along the rig 12, the platform 30, the legs 32 thereof and then into the subsoil through current lines 18. The part of the current which flows into the rig 12 and into the platform 30 is symbolized by arrows 22.

In conformity with the invention and in a manner comparable with the onshore technique described above with reference to Figure 1, the current flowing along the string of rods 14, above the surface of the sea, and below the platform 30, is used to detect the modulated electromagnetic signals radiated by the radiating antenna 16.

More specifically, the magnetic induction produced by the string of rods 14 at this level under the effect on the current flowing in the string of rods and then in the rig 12 and in the platform 30 is measured while electromagnetic signals are being radiated. To this end, a directional magnetometer 24 is used, being fixed on the string of rods immediately above the sea and below the platform 30. The orientation and the characteristics of this directional magnetometer are moreover identical to those which have been described with reference to Figure 1 and likewise the receiver circuit 28 to which the magnetometer is connected by electrical conductors 26. The only difference is that the receiver circuit 28 is installed in this case on the platform 30.

Use of the detection apparatus at the surface in conformity with the invention in the case of an offshore well exhibits the same advantages as in the case of an onshore well. However, it is important to note that the simplicity of implementation in this case is an even more decisive advantage, since use of electromagnetic telemetry can be envisaged to advantage in the case of an offshore well, which was not possible in practice for operational reasons when using conventional reception techniques.

Trials made at sea, with the aid of a commercially available magnetometer and without special precautions, have shown that the use of the detection apparatus in conformity with the invention makes it possible to detect and decode electromagnetic signals radiated downhole with very high sensitivity. These trials have also confirmed that the implementation of such an apparatus is much easier, less costly, and less dangerous than using two electrodes embedded in the bottom of the ocean.

CLAIMS

1. A method of detecting electromagnetic signals in real time and at the surface, which signals are radiated down a well from a string of rods suspended from a rig, comprising the steps of measuring the magnetic induction produced at the surface by the string of rods in response to a current flowing down the string of rods and along the rig during the radiation of the electromagnetic signals.

2. A method according to claim 1, wherein the magnetic induction is measured by means of a directional magnetometer fixed on the string of rods in such a manner as to make a measurement in a direction that is substantially orthogonal to the axis of the string of rods.

3. A method according to claim 1 or 2, applied to an offshore well, wherein the magnetic induction is measured immediately above sea level.

4. A method according to claim 1 or 2, applied to a well on land, wherein the magnetic induction is measured immediately above the ground.

5. Apparatus for detecting electromagnetic signals in real time and at the surface, which signals are radiated down a well from a string of rods suspended from a rig, comprising means for measuring the magnetic induction produced at the surface by the string of rods in response to a current flowing along the string of rods and along the rig during the radiation of the electromagnetic signals.

6. Apparatus according to claim 5, wherein said means for measuring the magnetic induction comprises a directional magnetometer fixed on the string of rods in an orientation for making a measurement in a direction substantially orthogonal to the axis of the string of rods.

7. Apparatus according to claim 6, wherein the magnetometer is fixed on the outside of the string of rods.

8. Apparatus according to claim 5, wherein, with the well being situated offshore, said means for measuring the magnetic induction are located immediately above the surface of the sea.

9. Apparatus according to claim 5, wherein, with the well being situated on land, said means for measuring the magnetic induction are located immediately above the ground.